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Estimating particulate pollution exposure in New Zealand: the HAPiNZ method

Simon Kingham[1], Gavin Fisher[2], Simon Hales[3], Ionara de Lima[1] and Phil Bartie[1]

[1] GeoHealth Lab, Department of Geography, University of Canterbury
[2] Endpoint Ltd, Auckland
[3] Department of Public Health, Wellington School of Medicine and Health Sciences, University of Otago

What is exposure

"the concentration of the pollutant in the air multiplied by the population exposed to that concentration over a specified time period."

- www.arb.ca.gov/html/gloss.htm CARB, 2002

Various measurement methods

- Dispersion models – *rubbish in, rubbish out*
- Regression based approaches
- Central site monitoring

Central site monitoring

Central site often used as exposure estimate

BUT - Intraurban spatial variation often as great as inter-urban – need for good spatial estimates

- Jerrett M, Arain A, Kanaroglou P, Beckerman B, Potoglou D, Sahsuvaroglu T, Morrison J, and Giovis C, 2005, A review and evaluation of intraurban air pollution exposure models. *Journal of Exposure Analysis and Environmental Epidemiology* 15, 185-204.
- Wilson J, Kingham S, Pearce J and Sturman A, 2005, *A review of intraurban variations in particulate air pollution: Implications for epidemiological research.* Atmospheric Environment, 34, 6444-6462.

Background to research

Funded by Central Govt. (Ministries of Transport, Health and Environment)

Time – 3 years

Research Team - UC Geog, Govt Research Institute (Landcare), Schools of Medicine, Consultants

UC Geography - Air Quality Assessment and Exposure

Pollution exposure map of NZ

Health and Air Pollution in New Zealand (HAPiNZ) study

Applicable for all NZ including 'data-sparse' areas

Research aims

Develop exposure estimates for New Zealand for 2001

- Initially PM_{10}
- Sub-divided by source
  - Domestic
  - Traffic
  - Industry
  - Background
- Especially for areas with limited or no pollution monitoring
- Based on *available* data for Census Area Units (CAUs) using GIS
- Urban areas - <5,000 people
  - 68 urban areas
  - 3m people (of total population of 4.1m)
  - 73% of population

Method

Developed and tested based on accurate spatial data for Christchurch

- The Air Pollution Model' (TAPM) - PC-based atmospheric dispersion model which combines meteorological and emissions data
- Sub-divided by source (domestic, vehicle, industry)
- Zawar-Reza *et al*, 2005, *Evaluation of a mesoscale air pollution model for Christchurch, New Zealand*. Science of the Total Environment, 349, 249

Domestic

Regression based approach – TAPM output as dependent variable

Census data for "domestic pollution" indicators

- Method of home heating - wood, coal – density per sq km
  - Secondary heating contribution from other CAUs
- Population density

Other factors from GIS:

- Altitude (and relative altitude)
- Slope
- Proximity to other CAUs
- Proximity to coast

Domestic

Wood use and availability

- surveys within several urban areas extrapolated to similar areas
  - MfE, 2003, Emission inventories for PM10 in New Zealand. Air Quality Technical Report No 38, Ministry for the Environment, Wellington, NZ.

Meteorology

- number of days in winter (May-Sept) where the minimum temp is below 5 degrees C, mean wind is below 3 m/s and there is no rainfall, as a proportion of the number of days those conditions were experienced in Christchurch.

Domestic

Final model

Domestic (μg m-3) = 3.77 + (0.021*woodfires*) * *met* * *wooduse*

Where:

woodfires = wood fires per square kilometre

met = number of *possible* pollution days relative to Christchurch

wooduse = estimated area wood use factor

Traffic

Regression based approach – TAPM output as dependent variable

Census data for "vehicle pollution" indicators

- Vehicle ownership
- Mode of travel to work
- Population density

Other factors from GIS:

- Proximity to other CAUs
- Altitude (and relative altitude)
- Road density (estimated from a GIS)
- Vehicle kilometres travelled per square kilometre (estimated using the MoT Crash Analysis System).

Traffic

Meteorology

- number of days in where the mean wind is below 3 m/s and there is no rainfall, as a proportion of the number of days those conditions were experienced in Christchurch.

Traffic

Final model

Vehicle (µg m-3)= 2.8 + (0.054*VKT*) + (0.032*CAUsin5K*) - (0.0019*HDiff2K*) * *met*

Where:

- *VKT* = Million vehicle kilometres travelled per square kilometre
- *CAUsin5K* = number of CAUs within 5 km of the CAU centroid
- *HDiff2K* = maximum height difference between CAU centroid and all points within 2 km
- *met* = number of *possible* pollution days relative to Christchurch

Industry

Minor sources

Population density approach

TAPM output for CAUs with no major source compared with population density (50% assumed from major sources)

Final model - 1-9.99 pp hectare = 0.5 µg m-3
10-19.99 pp hectare = 1.0 µg m-3
20-29.99 pp hectare = 1.5 µg m-3
30+ pp hectare = 2.0 µg m-3

Industry

Major sources

All processes discharging > 10 kg/day – data from Regional Councils at CAU level

Dispersion models and meteorology data not applicable

Mass converted to volume over which spread upwards and outwards constrained by mixing height (mean 435m)

Pollution cone overlaid onto 250m raster grid and deposited mass calculated

Totals for all sources calculated and converted to CAUs using GIS

Related to TAPM Christchurch output (minus *Minor sources*)

Generated regression equation applied to whole country

Background

Background and natural sources including windblown dust and sea salt

Based on geographical characteristics of areas and local knowledge about particulate pollution

No specific monitoring for natural or background concentrations

Values estimated from monitoring when wind direction from areas with no anthropogenic sources

Patterns established – such as proximity to:

- the coast (e.g. salt)
- agricultural areas (e.g. dust)
- forested and bush areas (e.g. pollen)

Background

Final Model

Category	**Background PM10 value**
Inland	2 µg m-3
Urban flat	4 µg m-3
Urban valley	6 µg m-3
Coast – not exposed	2 µg m-3
Coast – exposed	8 µg m-3
Coast – highly exposed	16 µg m-3

Model results

Descriptive statistics (µg m^{-3})

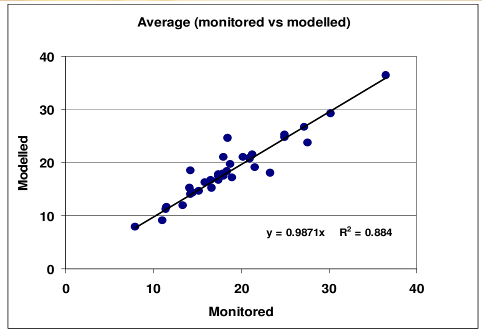
	Domestic	Vehicle	Industry	Background	Total
Mean	4.6	5.0	1.5	4.0	15.1
Median	3.1	5.1	1.4	4.0	14.3
Min	0.0	0.0	0.0	2.0	7.1
25^{th}%	1.5	3.5	1.0	2.0	12.2
75^{th}	5.7	6.2	2.1	4.0	16.8
Max	22.3	17.0	3.4	16.0	36.0
Stdev	4.4	1.9	0.8	1.9	4.2

Model results

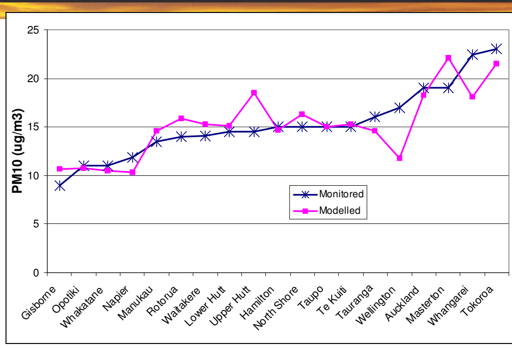
Source contribution

	N	% Dom	% Veh	% Ind	% Back
All	970	24	36	9	25
All – Above 75th% (16.8µg m-3)	244	50	23	7	19
North Island – All	736	17	41	11	26
North Island – Above 75th%	82	34	38	8	21
South island – All	234	50	21	6	19
South island – Above 75th%	162	54	20	6	18

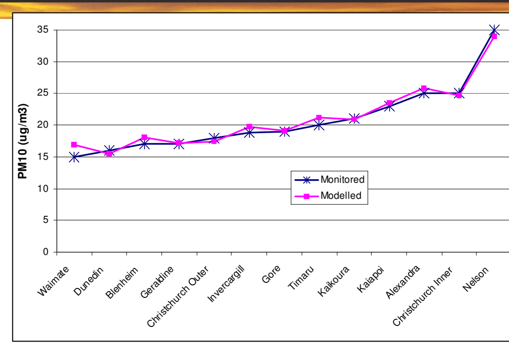
Model validation - vs monitoring



Model validation – North Island



Model validation – South Island



Model validation

- Good r^2 value (0.88) – similar to other regression based approaches
  - Possible issue of poorly located monitors
  - No apparent difference between high and low values
- Better in South Island
  - Model works better for domestic sources
  - Less well for industry

Conclusions

- Attempt to model PM_{10} concentrations in areas of sparse data
- Fine spatial resolution
- Sub-divided by source
- Based on 'available' and GIS'd data
- Compared to monitored data
- r^2 values of 0.88
- Better in South Island than North island – better for domestic sources